# TRD Gas system Summary and Specifications

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# 1. Abstract

The Transition Radiation Detector (TRD) for the AMS-02 detector requires a detection medium of mixed Xenon and Carbon Dioxide gas in a ratio of 4:1 by volume. This gas has to be stored, mixed and distributed through the TRD. This is accomplished by the TRD Gas System, described in this document.

This description of the TRD Gas System is as follows. The next section contains a functional description. Section 3 contains the details of the mechanical design, followed by the electrical controls in Section 4. The components are listed in Section 5 with the System assembly described in Section 6. Testing and verification are in Section 7 and Operations are in Section 8. All symbols for gas components used in the document are explained in Appendix A. The naming convention for the gas components is explained in Appendix B. Appendix C contains a list of contact persons for the TRD gas system. Appendix D contains the materials list and Appendix E contains the weight estimate for the TRD gas system

# 2. Functional Description

The Transition Radiation Detector (TRD) is located on top of AMS-02 and functions to differentiate between electrons and protons. Energetic electrons passing through the radiator material in the TRD emit X-rays collinear with the electron trajectory. The X-rays are detected in layers of proportional tubes between the radiator layers. Efficient detection of X-rays requires the gas in the proportional tubes to have large nuclear charge, allow fast drift of ionization electrons without loss and have high gain (approx. 3000) in the amplification region around the sense wire. Studies have shown $Xe:CO_2$ meets these requirements.

The TRD Gas system performs the following functions:

- Stores sufficient gas for the 3-5 year AMS-02 mission with a safety margin of four.
- Transfers new gas to the TRD each day.
- Circulates the gas and monitors the gas content continuously.

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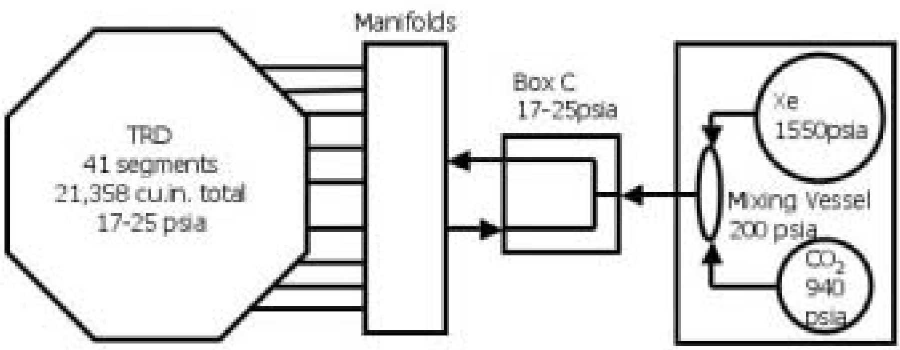



Figure 1 TRD Gas System general layout.
The 41 TRD segments are connected through manifolds to Box C containing controls, monitors, and recirculation pumps. Box S provides Box C with pre-mixed gas from gas supplies in a limited transfer volume (approx. 1 liter). A feed control between Boxes S and C is activated by computer approximately once a day. The general layout is shown in Figure 1. The 41 sealed TRD segments of approx. 430 cu in. each are held at 17.4 psi. Box C has an estimated volume of less than 150 cu. in., held below 25 psia by relief valves.

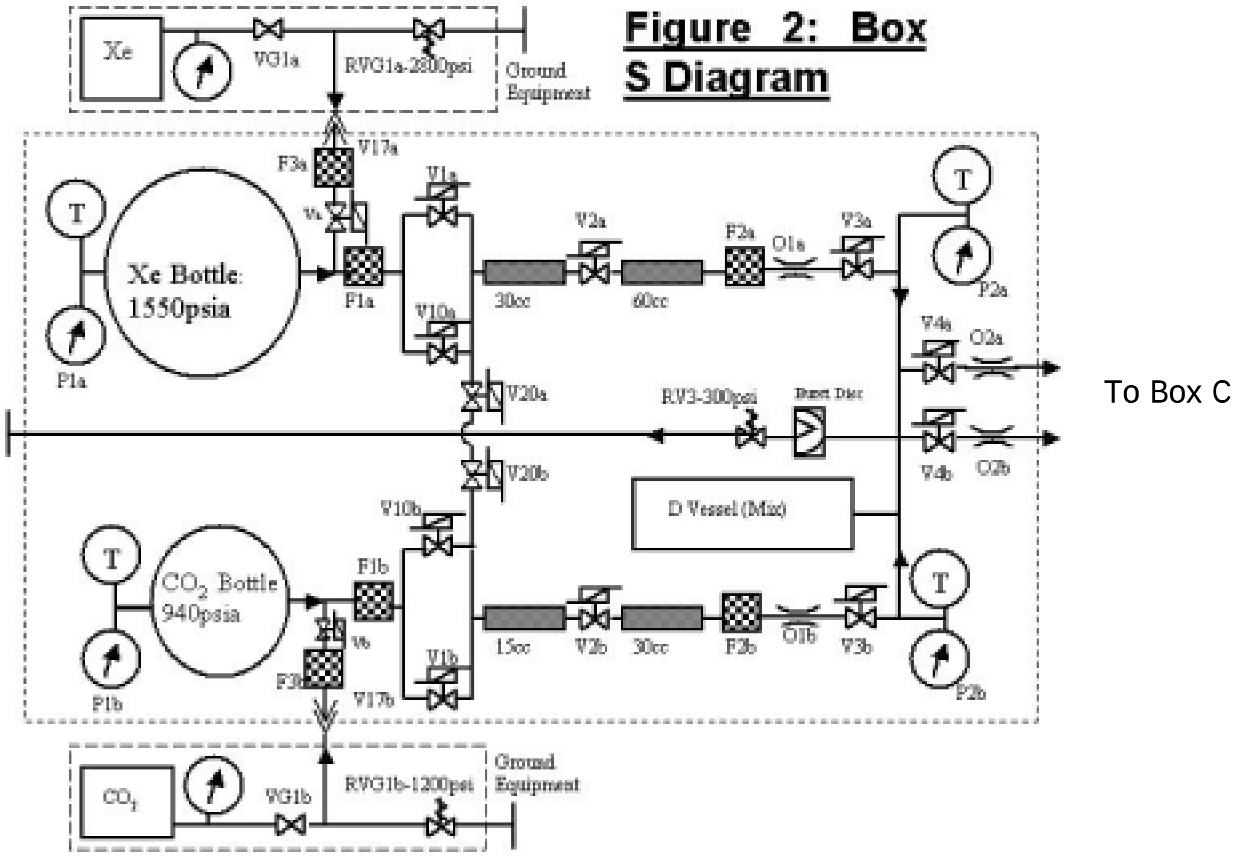


Figure 2 Box S Schematic.

The schematic for Box S is shown in

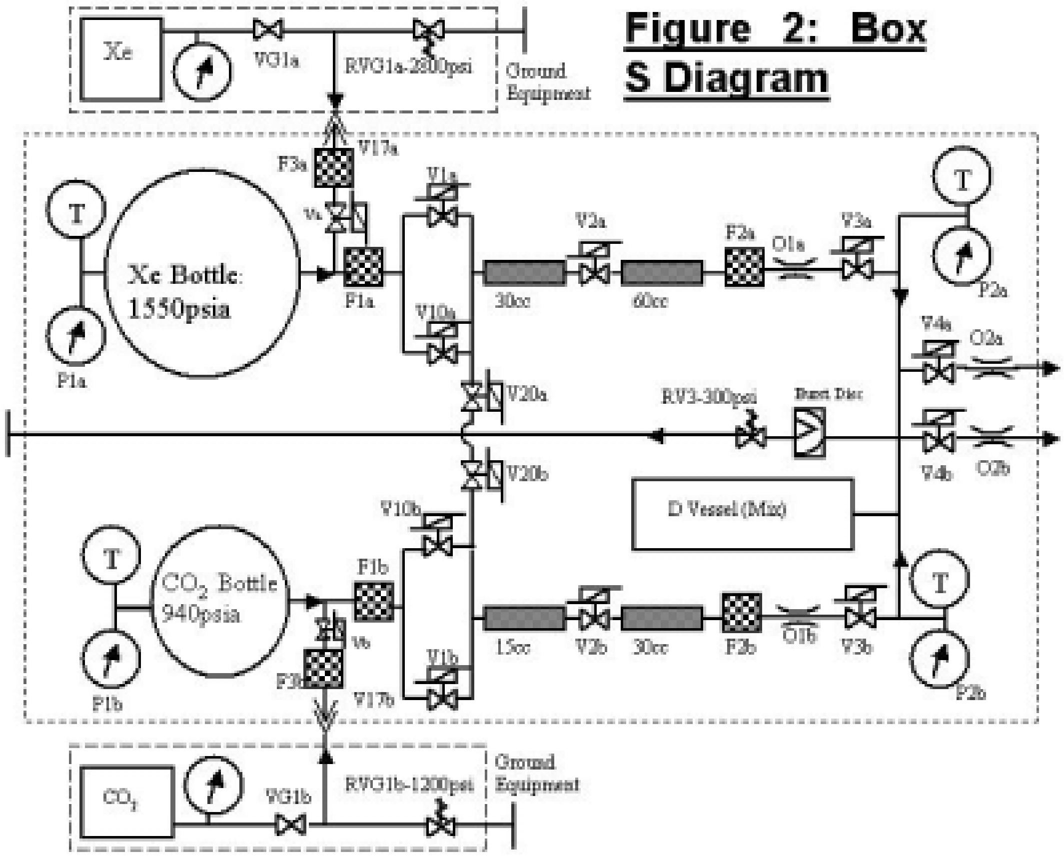



Figure 2. Two storage vessels store the xenon and carbon-dioxide separately. Two mixing circuits convey the gases to the mixing vessel where the 4:1 mixture is made. A system of valves then allows the transfer of the gas from the mixing vessel to Box C. At all points, the valves have a two fold redundancy. Leak-before-burst vessels ensure safety in the event of high temperatures causing over pressure in the vessels during a time when gas cannot be vented, such as when the system has no electrical power.

Figure 3 shows the Box C schematic. Gas from Box S passes through the transfer valves V6a-b and V18a-b. Two pumps circulate the gas through the TRD volume in order to keep the gas mixed and allow the $CO_2$ sensor and gain monitor tubes to assess the properties of the gas. The pumps and $CO_2$ sensor are mounted inside a gas tight vessel; in the event of a pump or valve failure, pressure integrity of the system will not be lost.

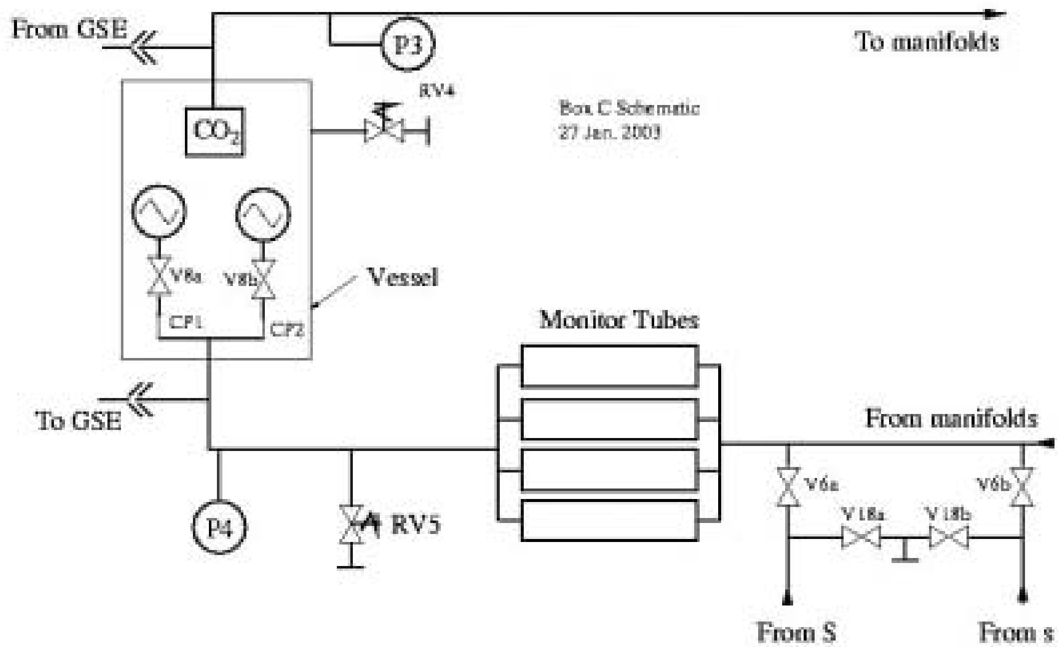



Figure 3 Box C schematic.

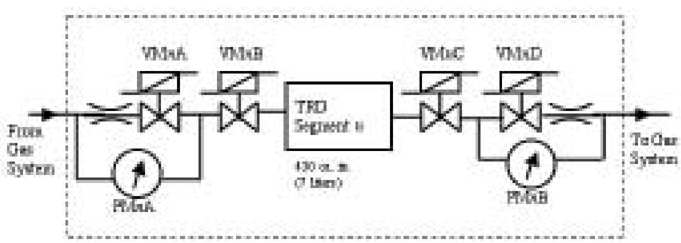



Figure 4 One of 41 TRD manifold segments.

One manifold segment is shown in Figure 4. Each manifold segment has two valves and one pressure sensor at each end. The valves allow the isolation of TRD segment in case a leak occurs and the pressure sensors allow detection of leaks. All valves are computer controlled; If there is a large leak in any segement, that segment is closed by the control computer. If there is a large pressure drop at P3or P4 in Box C, all valves are closed by the gas system electronics, even if the computer is not running.

## 3. Mechanical Description

Box C and S form one mechanical system mounted on AMS-02 between the upper and lower cross beams of the USS, Figure 5.  Box S consists of a large base-plate which carries the mechanical loads of the gas vessels and plumbing to the USS, Figure 6.

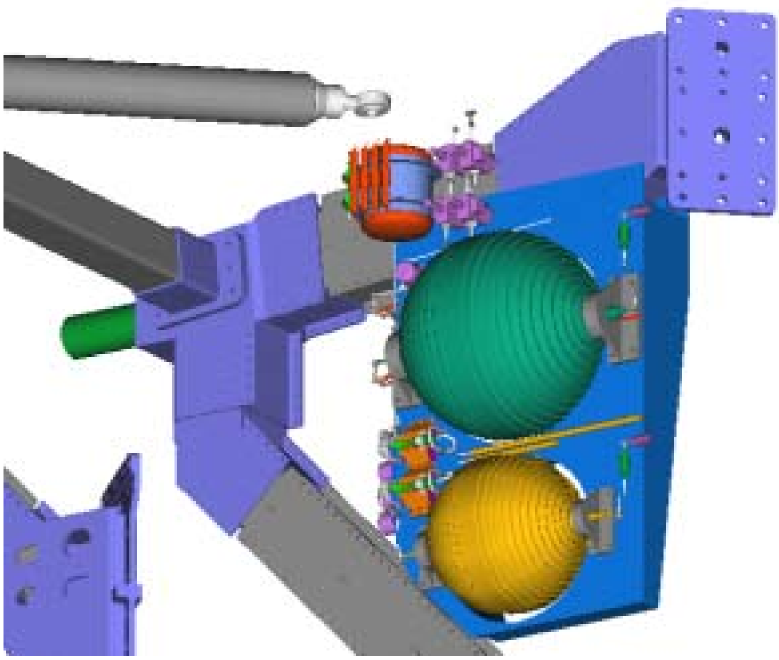


Figure 5 Mounting of TRD gas system Box S and C on USS.

Box C, Figure 7, mounts onto the base-plate near the top connection to the USS. The forty-one manifolds are distributed around the top of the octagon,

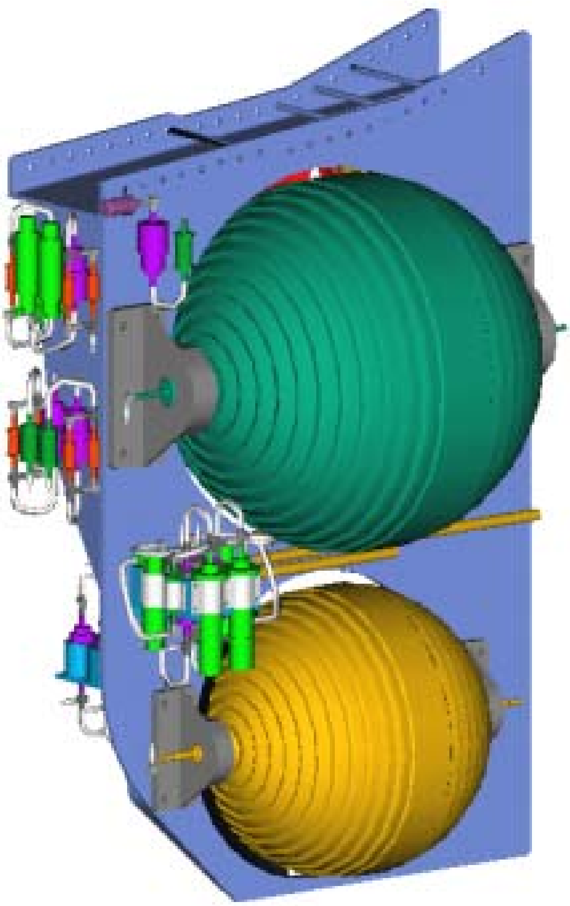


Figure 6 Box S mechanical design.

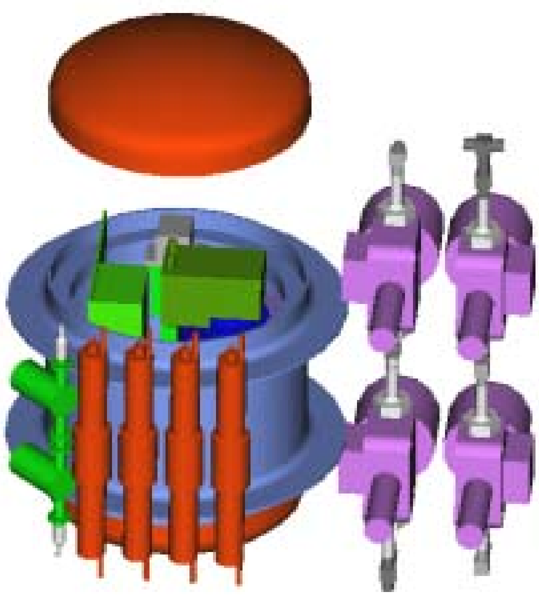


Figure 7 Box C mechanical design.  The vessel cover is open to show the pumps, valves and sensor inside the vessel.

## 4. Electrical Control

The TRD Gas systems is controlled via the TRD gas system electronics crate. The layout of the crate is given in Fig. 8. Box S is controlled by the double redundant UGBS electrics cards, Box C by the double redundant UGBC card and the manifolds by the double redundant UGFV cards. The numbers and types of signals for Box S are shown in Table 1. All signals have been specified except for the number of Dallas temperature sensors. The electrical signals for Box C are shown in Table 2. Pinouts for connectors have been defined as well.

| # of Conductors | Purpose | Component | Voltage | Current | Description |
|---|---|---|---|---|---|
| Power | | | | | |
| 48 = 2 x 2 x 12 | Valve Power | MV197 | 24V | 1.0A | Hold Valve Open When Current is On |
| 16 = 2 x 2 x 4 | Pressure Sensor Power | GP:50 | 24V | 100mA | |
| Signals | | | | | |
| 12 = 3 x 4 | Pressure Sensor Readout | GP:50 | 0—5V | n/a | Pressure and Temperature Analog Value |
| | Dallas Sensor Quantity TBD | | | | Read by USCM |

Table 1 Box S electrical signals.

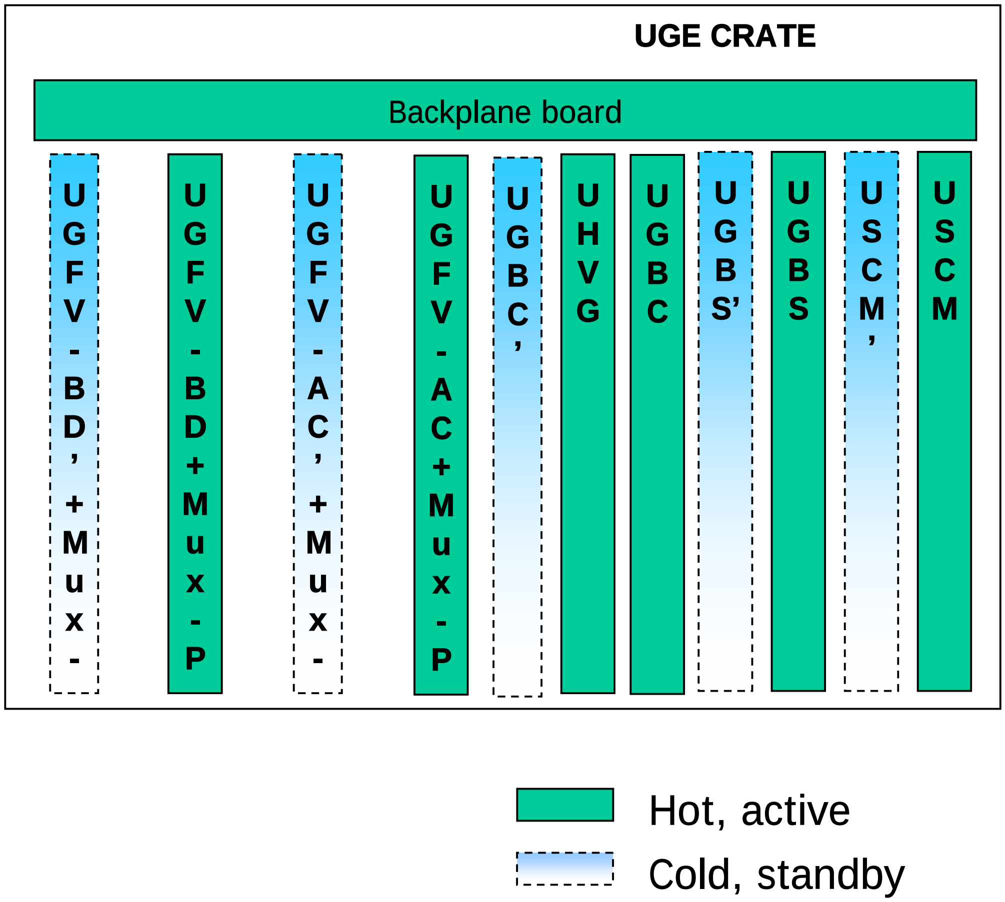



Figure 8 Layout of the TRD Gas System Electronics Crate (UGE crate)

The manifolds are controlled through the UGVF cards. One of two redundant Universal Slow Control Modules (USCM) scans the readings of the pressure sensors in the manifolds. The readings are reported to the main AMS-02 data computer (JMDC). If the JMDC detects a leak, it will close the corresponding manifold valves to isolate the leaky segment.  This operation can also be performed from the ground.

| Component | No. | Signal | Max. V (V) | Max. I (A) | Cont. power (W) |
|---|---|---|---|---|---|
| Pump | 2 | Power | 12 | 0.1 | 1.2 |
| | 2 | Return | | | |
| | | | | | |
| Temp. sensors | 2 | Excitation | 24 | | |
| | 2 | Digital | | | |
| Flip valves | 2 | Open | 12 | 0.1 | |
| | 2 | Return | | | |
| MCA | 1 | Power | 12 | 0.1 | |
| | 1 | Return | | | |
| | 3 | TTY | 5 | | |
| Fill valves | 4 | Power | 24 | 1 | |
| | 4 | Return | | | |
| CO2 | 2 | TTY | 5 | | |
| | 1 | Power | | | |
| | 1 | Return | | | |
| Tube Amp | 4 | Address | 5 | | |
| | 1 | Power | 5 | | |
| | 1 | Return | | | |

Table 2 Box C electrical signals.

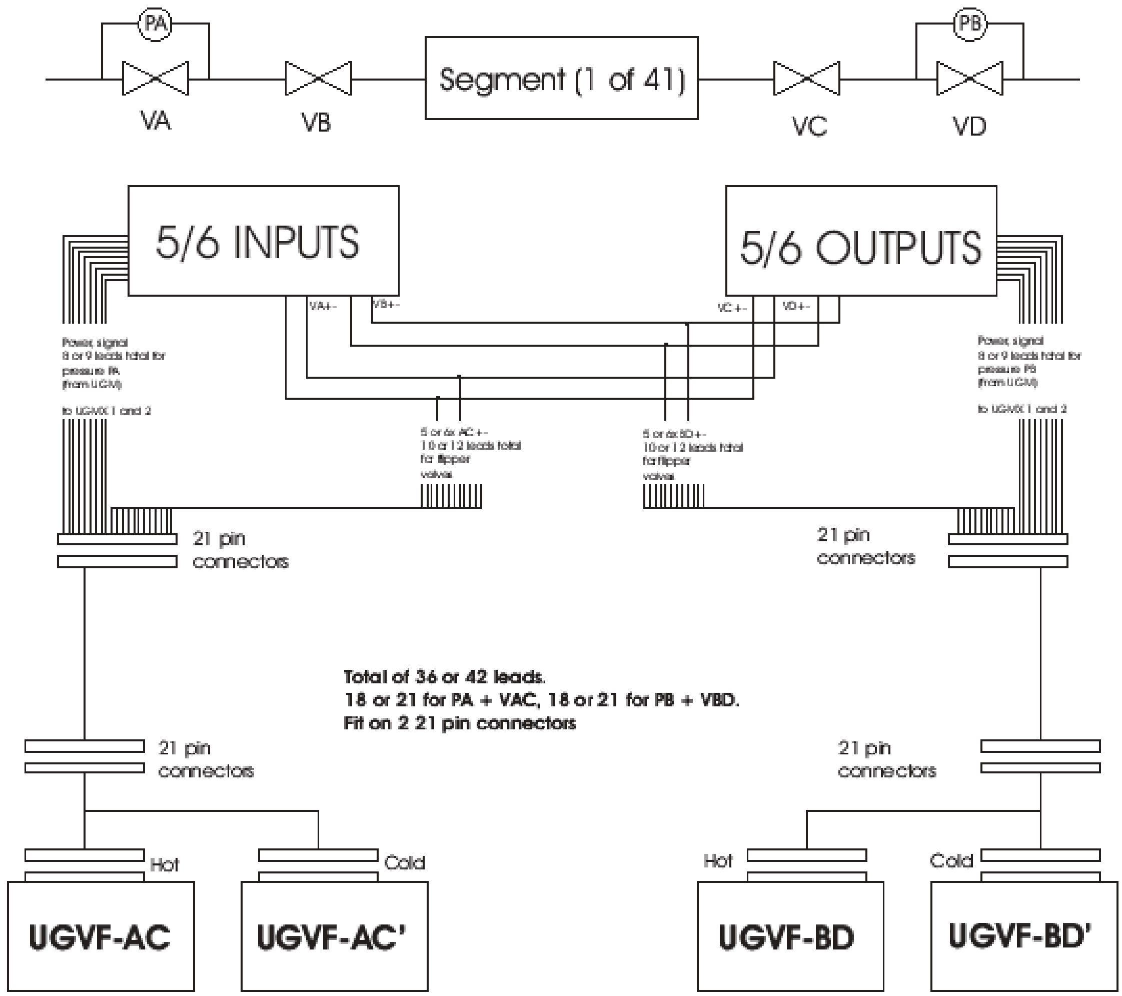



Figure 9 Manifold electrical cabling layout.

## 5. Gas System Components

All components for Boxes S and C and the manifolds have been identified and are undergoing tests to ensure their performance. Unless otherwise specified, all tubing is 1/8" stainless steel with welded joints. The main items of interest for Box S are the three storage vessels for xenon, carbon-dioxide and mixing. All are produced by Arde (Norwood, NJ).

The xenon tank has an MEOP/MDP of 3000 psia and is designed to operate over a range of –60 to 150F (-51C to 65C) with the normal operating pressure being 1550 psig at a normal operating temperature of 77F. The proof test factor is 1.5 and minimum burst factor is 3.1. Leak-before-burst ensures safety in all circumstances. The xenon tank has been used in space-flight before in the plasma contactor unit for the ISS and the NSTAR ion drive engine. The external load test was performed to 8.9 grms at 0.08 $g^2$/Hz on all axes.

Dimensions are given in Table 3.
Like the xenon tank, the $CO_2$ tank is a composite over-wrapped vessel. MDP/MEOP is 3200 psig and the tank is designed to operate over –100 to 300F. The tank is leak-before-burst. Normal operating pressure is 940 psid at 77F. The proof test factor is 1.5 and the minimum burst factor is 2.125. Dimensions are given in Table 3.

| | Xenon | $CO_2$ | Mixing |
|---|---|---|---|
| Model | D4815 | D4816 | SKC 13181 |
| OD (in.) | 15.37 | 12.42 | |
| Volume (in.$^3$) | 1680 | 813 | 61 |
| Tank weight (lbs) | 17 | 9.5 | |
| Xenon weight | 109 | 11 | |
| Material | Composite overwrapped stainless steel | Composite overwrapped stainless stell | Stainless steel |
| Arde qualification documents | EG10330, N/C, July 6,2001 | EG10331, N/C, July 6, 2001 | EG 10348, N/C, Nov. 6, 2001 |

Table 3 Arde vessel parameters.

The mixing task MEOP is 300 psig and operation range is –100 to 300 F. Normal operation is 200 psig at 77F. Proof and minimum burst factors are 2.0 and 4.0, respectively. Other Box S components are listed in Table 4. The MV197 hermetically sealed valves have undergone extensive testing in a magnetic field. Box C and manifold components are listed in Table 5. All mechanical components (pumps and valves) are undergoing endurance tests at temperatures spanning the operation range and in a magnetic field.

| Item | Quantity | Type | Peak Requirement | Duty Cycle |
|---|---|---|---|---|
| Hermetic Solenoid Valves – Fill ports | 2 | Marotta MV197 | Will be operated only during ground operations | Open during filling procedure. |
| Hermetic Solenoid Valve – Other | 12 | Marotta MV197 | 1A @ 24VDC | minutes/day |
| Pressure and Temperature Sensor | 4 | GP:50 : 7900 | 100mA @ 24 VDC | cont. |
| Xe Vessel | 1 | Arde D4815 | | |
| CO2 Vessel | 1 | Arde D4816 | | |
| Recoil Valves With Caps | 2 | Schwer | | |

| | | |
|---|---|---|
| Relief Valve (300 psi) | 1 | Marotta |
| 7 micron gas filter | 6 | Swagelok, Arde Mount |
| Flow Restrictors | 4 | Lee Company JEVA Jets |
| Cabling | 4 connectors + cables | Glenair MIL-PRF 83513 Pigtails |

Table 4 Box S components.

| Item | quant | Type | peak req | duty |
|---|---|---|---|---|
| Burst Disk | 1 | BS&B Safety Systems Inc. | | |
| Pump | 2 | KNF Neuberger NMP30 | 12 or 24 V, 0.1 A | one on continuously |
| Pressure sensor | 2 | GP:50 7950 | 24 V, 1 W | cont |
| CO2 analyzer | 1 | SquareOne 2115 | 12 V, low power | cont |
| MCA | 1 | Amptek 8000A | 12 V, low power | ~min/day |
| Flipper valves | 166 | Burkert 6123 or 6033 | 12V, 0.1A | ~sec/year |
| Marotta valves | 4 | Marotta MV100 | 24V, 1A | ~min/day |
| Calibration tubes | 4 | MIT | | |
| Relief valves | 2 | Marotta | | |
| Self-sealing connectors | 2 | Schwer | | |
| Electrical connectors | 2 | GlenAir | | |
| Hermetic connectors | 1 | PAVE | | |
| Cabling | | GlenAir | | |
| Piping | | 1/8" stainless steel | | |
| Pipe fittings | | Swagelok weld fittings | | |
| Gas connections | | Swagelok VCR face seal | | |
| Tube amplifier | | MIT multilayer PCB | | |
| Pump canister | | Marotta | | |
| Manifold Pressure sensors | 82 | Honeywell 26PCCFA6D | | |

Table 5 Box C and manifold components.

# 6. System Assembly

Two versions of both Box S and C will be built: an engineering version and a flight version. The engineering version of Box S has been built at CERN, Figure 9. The flight unit will be built by Arde beginning in April, 2003. All construction will take place in clean room conditions and all welding will follow MSFC-SPEC-560A. Electrical connections will follow NASA-STD-873.3.

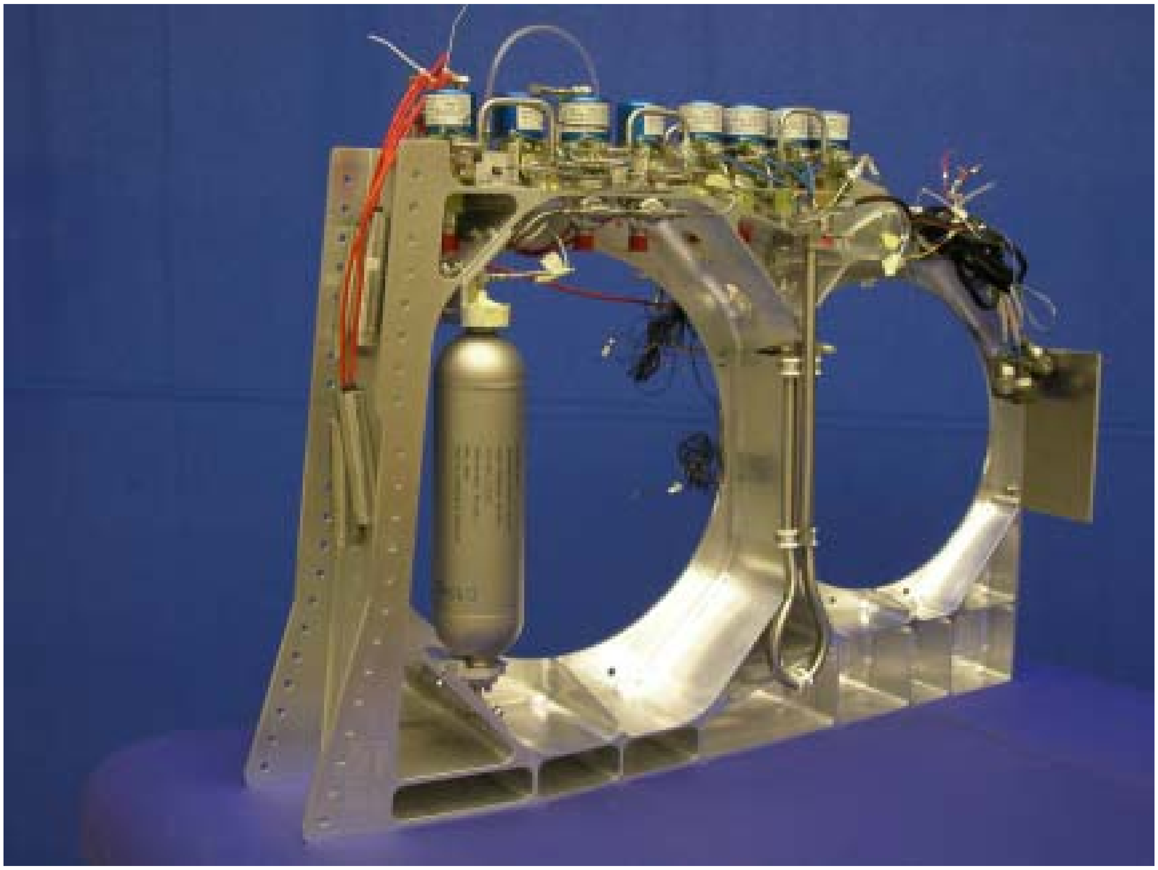


Figure 9 Photogtaph of Box S engineering unit.

The Box C assembly will be built the Marotta Corp. of Boonton, NJ.  Marotta will use tested components from MIT and all construction will be in clean room conditions.  The engineering unit will be ready in Spring 2004 and the flight unit in Fall 2004.  The ROM from Marotta is included in the data pack.
The manifold system in currently being fabricated at CERN and a preliminary version installed on the AMS mockup.  The flight version of the manifold blocks will also be fabricated at CERN.

# 7. System Testing and Verification

All components of the TRD Gas System have or are undergoing extensive testing to ensure operations in all circumstances.  The engineering version of Box S has undergone a first vibration test in Rome in March 2003. The preliminary report is included in the data pack, and the analysis is still ongoing.  The assembled Box S/C engineering system will undergo vibration test together. The vibration tests are done for missions success reasons. A detailed Finite Element and Modal Analysis of Box S was done prior to the vibration test to determine the margins of safety and first resonance frequency of the mechanical support of Box S. It was determined from this analysis that all margins of safety are positive and that

the first resonance frequency is above 50Hz, satisfying mission safety requirements. A copy of this analysis is attached.
The engineering version of Box C will undergo functional and vibration tests at Marotta and the assembled Box S/C flight hardware will be thermal vacuum tests at Aachen.  The manifold valve blocks have been vibration tested at Aachen.

## 8. Gas System Operations

The TRD Gas System is controlled by the AMS-02 slow control system via the UGBC, UGBS and UGVF cards in the TRD gas system electronics crate.  The system has been designed in such a way so as to be safe in all circumstances, even when the AMS-02 is out of contact with ground control or the ISS, or during interruption of power to the TRD gas system.

### a. Ground operations

The ground operations consists of three tasks: TRD testing, gas filling and gas recovery.  TRD testing is the operation of the TRD during functional testing of AMS-02 prior to processing and is similar to on-orbit operation.  The primary difference is that during pre-flight testing, the pump vessel in Box C will be bypassed by ground support equipment consisting of a circulation pump (identical to the one being used in flight) and more extensive gas monitoring. This is being done to prevent wear on the flight pumps during ground testing. Gas filling will take place as late as possible before processing and is the filling of the xenon and carbon dioxide vessels with the gas for flight.  We are currently working with NASA mission management to obtain the Ground Support Equipment (GSE) necessary for gas filling.  Gas recovery will take place in case the gas must be removed from the storage vessels.  Recovery will use the same GSE as filling.

### b. Flight operations

Flight operations has four categories: normal data taking, normal filling, startup and shutdown.  Normal data taking is the normal operation of AMS-02 with the gas circulating via Box C and Box S dormant.  For Box C normal inflight operation consists of recording information from all pressure sensors continuously and to periodically check the gas analyzer, Multichannel analyzer and

Nominally, filling takes place once per day and has two parts.  First, the xenon and carbon dioxide are mixed in the mixing vessel in Box S.  Second, the contents of the mixing vessel are transferred to Box C.  The mixing is carried out by the JMDC and initiated by ground control.  The mixing sequence is:

(1) Start with Known Mixture in D Vessel. Vent D if mixture unknown.
(2) Fill required  partial pressure of $CO_2$
(3) Fill required partial pressure of Xe.
(4) Vent to Box C when required.

(5) The transfer to Box C goes by the following sequence:
(6) Shut down CP1.
(7) Close V8a and V8b.
(8) (Confirm TRD manifolds are open)
(9) (Box S opens V4a)
(10) Open V6a.
(11) Read all pressures every ~1 sec
(12) (Box S closes V4a)
(13) Close V6a.
(14) Wait 5 seconds
(15) Open V8a.
(16) Start CP1.

Box C continuously monitors the pressure and composition of the gas and operation of the pumps and valves. Off nominal responses are given in Table 6.

| State | Problem | Action |
|---|---|---|
| **If CP1 is active, AND:** | | |
| CP1 current > 0.2V | Motor failure | Stop CP1. Close V8a. Open V8b. Start CP2. |
| P3 > 25 psi | Overpressure | Stop CP1. Open V18a and V6a for 5 sec. Repeat until P nominal. Restart CP1. |
| P4 > 25 psi (in normal ops) | Overpressure | Stop CP1. Open V18a and V6a for 5 sec. Repeat until P nominal. Restart CP1. |
| P4 > TBD psi (during fill) | Fill too fast | Interrupt fill: close V6a and V6b. Wait for pressure to drop. Resume fill. |
| $\lvert P3 - P4 \rvert < 0.1$ psi | Pump failure | Stop CP1. Close V8a. Open V8b. Start CP2. |
| (P4 < 14 psi) | Gas Leak | Stop CP1. Close V8a. Close TRD manifolds. |
| (P4 < 14 psi) | Gas Leak | Stop CP1. Close V8a. Close TRD manifolds. |
| (P4 < 14 psi) | Gas Leak | Stop CP1. Close V8a. Close TRD manifolds. |
| | | |
| **If CP2 is active, AND:** | | |
| CP2 current > 0.2V | Motor failure | Stop CP2. Close V8b. |
| P3 > 25 psi | Overpressure | Stop CP2. Open V18a and V6a for 5 sec. Restart CP2. |
| P4 > 25 psi | Overpressure | Stop CP2. Open V18a and V6a for 5 sec. Restart CP2. |
| P4 > 25 psi (in normal ops) | Overpressure | Stop CP1. Open V18a and V6a for 5 sec. Repeat until P nominal. Restart CP1. |
| P4 > TBD psi (during fill) | Fill too fast | Interrupt fill: close V6a and V6b. Wait for pressure to drop. Resume fill. |
| $\lvert P3 - P4 \rvert < 0.1$ psi | Pump failure | Stop CP2. Close V8b. |
| (P4 < 14 psi) | Gas Leak | Stop CP2. Close V8b. Close TRD manifolds. |
| (P4 < 14 psi) | Gas Leak | Stop CP2. Close V8b. Close TRD manifolds. |
| (P4 < 14 psi) | Gas Leak | Stop CP2. Close V8b. Close TRD manifolds. |

Table 6 Box C off nominal actions.

At startup, the is no specific action for Box S or the manifolds, all valves are closed. The Box C startup procedure is

(1) Confirm V18a, V18b, V6a, V6b, are closed.
(2) Open V8a, close V8b.

(3) Power up CO2 analyzer, send initialization commands
(4) Read all P, T, and query CO2 analyzer.
(5) Turn on CP1.
(6) Turn on high voltage to Tube 3, 4.
(7) Read all P, T, pump current, and query CO2 analyzer.
(8) Begin normal operations.

When AMS-02 is shut down, again no specific action for Box S or the manifolds are required. The Box C shutdown sequence is:

(1) Shut down CO2 analyzer.
(2) If on, shut down MCA.
(3) Stop HV to Tube 3 and Tube 4.
(4) If on, stop HV to Tube 1 and Tube 2.
(5) Stop CP1.
(6) If on, stop CP2.
(7) Shut V8a and V8b.
(8) Confirm V18a, V18b, V6a, V6b all closed.

# 9. Gas system safety

## a. Safety Box S

Ground Operations:

Pressure relief valves connected to filling device will add protection against overpressure during ground operations. Liquid gas transfer from 109 lb pre-weighed volume excludes overfilling. Different thread size on filling ports prevent the transfer of the wrong gas into a pressure vessel.

During Flight:

The gas system electronics will be designed so that the gas system is automatically taken to a “Safe Mode” in case of communication failure. For Box S this means all valves closed. The Marotta MV197 solenoid valves used in Box S are normally closed and remain in that state if there is a power loss.
Computer controlled solenoid valve V5 opens automatically whenever the pressure in the mixing vessel D exceeds 300 psig. Relief Valve RV3 adds redundant overpressure protection. All valves controlling high pressure gas are closed when power is off; hence the lower pressure parts are protected. The mixing vessel (D) is protected by three valves and a flow restrictor in series from the high pressure gas in the storage vessels, as well as relief valve and a venting valve (V5). Box C is protected from the pressure in the mixing vessel (<300psi) by two valves in series and a flow restrictor in a redundant configuration.
The total transfer of the limited 7l volume in the mixing vessel D into the TRD volume of 300 liters can at most cause a 2% pressure increase. Failure of any of the relief valves in the open position in Box S will release gas into the

surrounding area (into the payload bay of the shuttle for example). At STP the entire contents of the mixing bottle only occupies 0.01$m^3$ and would not significantly increase the pressure in the shuttle cargo bay.
All systems in Box S are two fault tolerant; no part of the system goes above its MOP when any two components fail.
If the valves in the Box S are all closed, gas would be trapped at high pressure in tubing between the valves. In no case does the trapped volume in a single buffer volume exceed 0.1 liters. The buffer volumes are constructed from the same tubing used in the construction and are not considered to be pressure vessels.

### b. Safety Box C

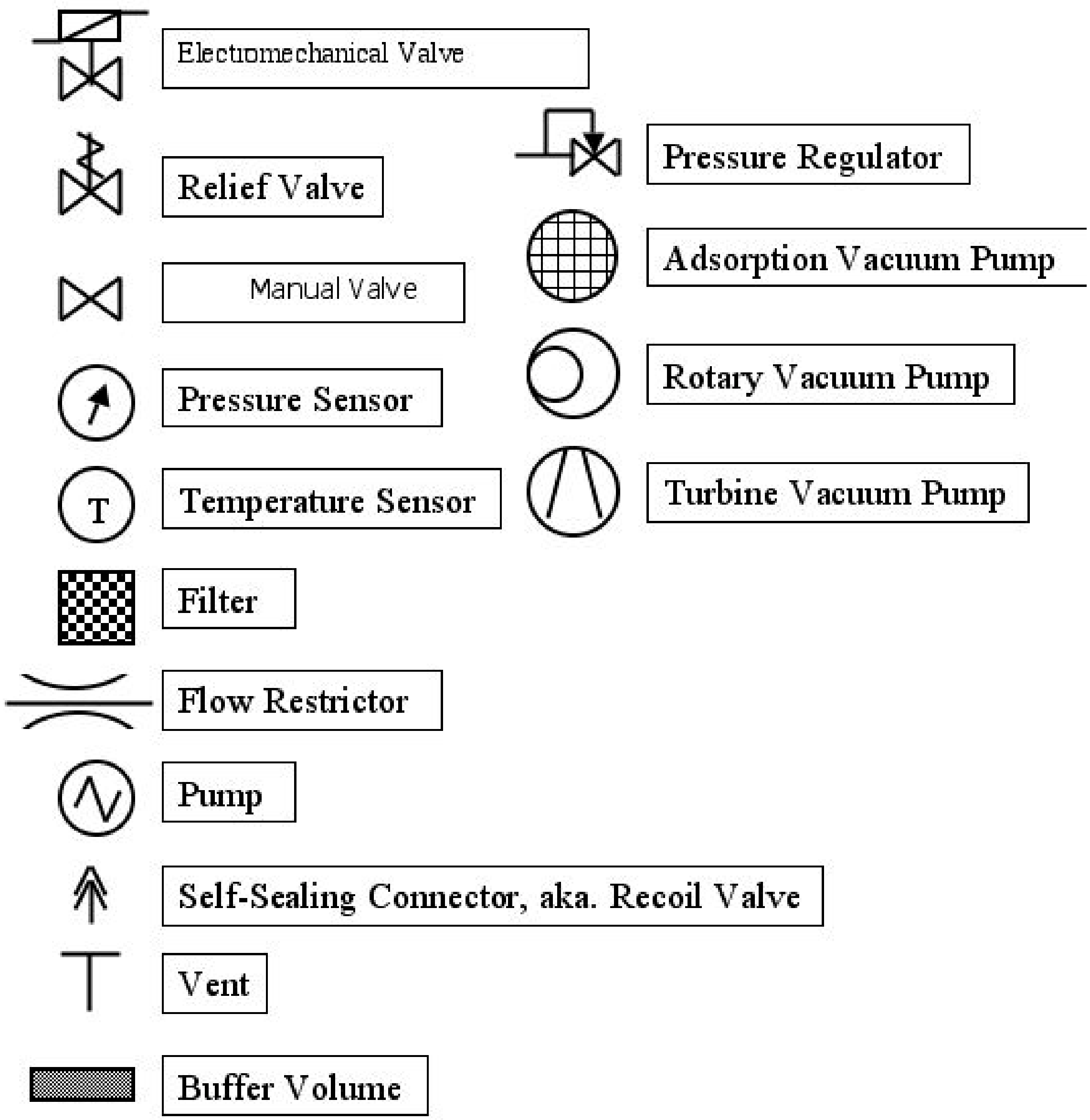
Box C operates below 1.4 bar (20.4 psia) and is two fault tolerant. The total gas volume contained in Box C is 0.011 $m^3$ (0.5 $ft^3$) (excluding the TRD Straw volume, each segment of which is protected by two valves) and the release of all gas would not cause a substantial change in the pressure in the shuttle payload bay. Box C is protected from higher pressures in Box S by valves V4a,b and V6a,b in series, as well as flow restrictors.

### c. Safety in Straw System

The straw volume is divided into 41 segments, each one of which is protected by automatic, double redundant valves as described above for mission success reasons. A leak in any segment would release about 0.007 $m^3$ (0.25 $ft^3$) of gas if the segment is successfully protected by the segment valves. The volume of the entire straw system is 0.3 $m^3$ (11 $ft^3$), the release of which would not change the pressure in the payload bay substantially.

# 10. Appendices

## a. Gas symbols



## b. Gas component naming conventions

Gas components have an abbreviation based on where in the system they appear. Abbreviations for pressure sensors and valves in Box S and Box C are in the form Px and Vx, respectively, where is x is the alphanumeric code uniquely identifying the component. In the manifolds the naming convention for valve and pressure sensors are VMx and PMx, and in the Xe handling system it is PHx and VHx. For components used in filling the Xe and Carbon Dioxide storage vessels it is PGx and VGx. Relief valves follow the same convention, except the V is replaced with RV.

## c. Contacts

| System | Name | Institute | Phone | E-mail |
|---|---|---|---|---|
| Overall, Box S | Prof. Ulrich Becker | MIT | 617-253-5822 | Becker@mit.edu |
| Box S | Mr. Reyco Henning | MIT | 617-258-7846 | Rhenning@mit.edu |
| Box C | Prof. Peter Fisher | MIT | 617-253-8561 | Fisherp@mit.edu |
| Manifolds | Dr. Joseph Burger | MIT/CERN | 41-22-767-5941 | Joseph.burger@cern.ch |

## d. Materials List

Size Code: A: Area($cm^2$)
V: Volume ($cm^3$)
W: Weight (gm)
0: 0 - 1
1: 1 – 10
2: 10 – 100
3: 100 – 1000, etc.

| Item | Type | Use and Location | Size Code | Comments |
|---|---|---|---|---|
| 1 | Stainless Steel | Piping, straps, support structure, pressure vessels, manifolds, filter elements, bodies of MV197 Valves. | A4,V4,W4 | |
| 2 | Aluminum Alloy | Support Structure, Body of MV100, Electrical connectors, Mounting for Manifolds and Solenoid | A5,V4,W5 | |

| | | | | |
|---|---|---|---|---|
| | | Valves | | |
| 3 | Nylon? | Wire Tiedowns | A2,V1,W2 | |
| 4 | Viton | O-Ring, pump diaphragm | A1,V1,W1 | |
| 5 | Tygon | Tubing for pump | A1,V1,W1 | |
| 6 | Epoxy Glue | Manifolds | A3,V3,W3 | Araldit AW13H with hardener HV991, manufactured by CIBA-GEIGY |
| 7 | Buna-N | Seal for MV100 Valve | A1,V1,W1 | Marotta MV100 |
| 8 | Nylon | Seat for MV100 Valves | A1,V1,W1 | Marotta MV100 |
| 9 | Vespel SP-1 | Seat for MV197 | A1, V1, W1 | Marotta MV197 |
| 10 | Fluorosilicone | O-ring inside MV197 Valve | A1, V1, W1 | Marotta MV197 |
| 11 | Carbon Steel ASTM A108 | MV197 Body | A3, V3, W3 | Marotta MV197 |
| 9 | Copper | Conductor for wiring, solenoid valve coils, flipper valves, pump | A2,V3,W3 | |
| 10 | Copper Nickel CuNi18Zn20 F34 | Tubing from TRD to Valves | W4 | |
| 11 | Mu Metal Or Vacoflux 50 | Magnetic Shielding for Manifold Valves | W4 | Mu Metal: Ni78Fe13Cu5Mo4 Carpenter Specialty Alloys, Crawley, West Sussex, UK VacoFlux 50: Vacuum Schmelze D63412 Hanau, Germany |
| 12 | Tefzel | Insulation for Wiring | A2,W2 | Glenair, per MIL-PRF-83513 |
| 13 | Carbon Fiber Composite | Pressure Vessels | A4,V4,W4 | See Arde Documentation |
| 14 | PEEK | Manifold Valve Body | W3 | Burkert Valve |
| 15 | Polyamide (PA) | Manifold Valve Coil Body | W4 | Burkert Valve |
| 16 | Krytox | Lubricant for Solenoid Valves | W1 | Marotta MV100 |

| | | | | |
|---|---|---|---|---|
| 17 | Xenon | Gas Supply | W5 | Gas/liquid |
| 18 | $CO_2$ | Gas Supply | W4 | Gas/liquid |
| 19 | FFKM (Sifriz) | Manifold Valve Diaphragm | W3 | Burkert Valve |

| Item No. | Commercial Identification | Chemical Nature Type of Product | Procurement Information Manufacturer Supplier | Use and Location | Mass |
|---|---|---|---|---|---|
| 1 | Corrosion Resistant Steel | ANSI 316L<br>X2 Cr Ni Mo 18-14-3<br>X2 Cr Ni Mo 17-12-2 | Norms: EN 10088 - ISO 1127<br>LO-GE No 510 | 6/5mm and 3/2.5 mm gas tubing<br>valves- box C<br>and 1.6mm o.d.<br>manifold to segment | <2.5kg |
| 2 | Corrosion resistant Steel | ANSI 316L/316LV | Cajon Micro-Fit Butt-Weld Fittings | Connections<br>to Box C and 3mm<br>tubing to manifolds | <500g |
| 3 | MuMetal<br>or Vacoflux 50 | Ni78Fe13Cu5 Mo4<br>FeCo alloy (50%Co) | Carpenter Specialty Alloys Crawley, West Sussex, UK<br>Vacuum Schmelze<br>D63412 Hanau, Germany | Magnetic shield for valves | <4kg |
| 4 | Aluminum Anticorodal | AW6082 | | Valve mounting | <2.5kg |
| 5 | Poly ether ether ketone | PEEK | | Valve Body | <800g |
| 6 | Simriz | FFKM | | Valve diaphragm | <350g |
| 7 | Polyamide | PA | | Valve Coil Body | <1100g |
| 8 | Araldite AW134<br>Hardener HY991 | | CIBA/GEIGY | gluing valves and pressure sensors to manifolds | <200g |
| 9 | 3M Scotchweld 2216<br>B/A Grey | | 3M | fixing screws in manifolds | <100g |

### e. Weight Estimate for Gas System

## AMS02 TRD Gas System Weight Budget

| Subsystem | Description | Mass (kg.) | Mass (kg.) |
|---|---|---|---|
| | | | |
| **Box S** | Xe Gas Supply | 49.50 | |
| | CO2 Gas Supply | 4.50 | |
| | Xe Vessel | 8.00 | |
| | CO2 Vessel | 4.30 | |
| | Support Plate | 14.50 | |
| | Support Plate Contingency | 5.00 | |
| | Marotta MV197(14) | 3.53 | |
| | Filters(6) | 0.48 | |
| | Pressure Sensors (4) | 0.72 | |
| | Piping + Buffer Volumes | 1.60 | |
| | Relief Valves | 0.50 | |
| | Schwer Fittings (2) | 0.14 | |
| | Mixing Vessel | 1.00 | |
| | Cabling, etc. | 1.00 | 94.77 |
| | **Total: Box S** | 94.77 | |
| | | | |
| **Box C** | Pumps | 0.56 | |
| | Pressure Sensors | 0.52 | |
| | Marotta MV100 Valves + Fittings | 1.66 | |
| | Flipper Valves | 0.03 | |
| | Manifold for Box C (internal to Box C) | 0.30 | |
| | Pump Housing | 1.70 | |
| | CO2 analyzer | 0.13 | |
| | CO2 analyzer housing | 0.90 | |
| | Proportional Tubes | 0.52 | |
| | Relief Valves (2) | 0.16 | |
| | Piping | 0.10 | |
| | MCA | 0.30 | |
| | Amplifier board | 0.10 | |
| | Support Structure | 1.00 | 7.98 |
| | **Total: Box C** | **7.98** | |
| | | | |
| **Manifolds** | Manifolds (16), incl: flippers, P-sensors, Al block, tubing | 4.10 | |
| | Mumetal shielding boxes | 4.70 | |
| | Cabling, etc. | 2.20 | |
| | Steel connection to Box C | 2.20 | |
| | VCR Fittings | 0.60 | |
| | Pressure Sensor readout cards | 0.50 | 14.30 |
| | **Total: Manifolds** | **14.30** | |
| | | | |
| | **Total for Gas System With Contingency** | **118.40** | 117.05 |
| | **Total for Gas System Without Contingency** | **113.40** | 112.05 |